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Relative Quality of Sheepskin Leathers Tanned with Sicilian and Three American Sumacs*

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INTRODUCTION

A report published in 1946[4] described two tannery experiments in which the value of Sicilian sumac and three species of domestic sumac for tanning sheepskin skivers was compared. The first experiment (called "1942-3 tests" in the report‡) showed that differences between leathers tanned with *Rhus coriaria* (Sicilian sumac) and those tanned with hand-picked leaves of either

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‡The change from' 'test" to "experiment" was made to avoid confusion with "physical tests" which is used later.

§Mean squares for species were not given in Table X of that article[4] but can be calculated readily from the data given.

R. copallina or *R. glabra* were slight and could not be detected by careful examination. Leaflets of *R. glabra* produced slightly better leather than leaves, but the cost of preparing leaflet material would not be justified for this type of leather.

The second experiment (1944 test), in which *Rhus typhina* was included, revealed that there were small differences related to species of sumac[5] in color, thickness, and stiffness of the resulting leathers. Weight per skiver was also related to species, provided a distinction was made between leaves and leaflets of *Rhus typhina*. The order of decreasing value of the species given by the tanner was: *Rhus coriaria*, *R. copallina*, *R. typhina* and *R. glabra*.

From the first tannery experiment, 40 skivers (10 from each of the 4 packs) and from the second tannery experiment, 165 skivers (15 from each of 11 lots), were retained for laboratory examination. These skivers were not subjected to the usual surface finishing operations. After tanning, they were dried, degreased by solvent, then fatliquored, toggled and redried. Results of the laboratory testing are reported here.

Tactual Evaluation

Feel or Quality of Tannage:—In judging lightweight leather, the tanner sums up much of his evaluation under the heading of "feel". Measurement of feel has been called "tactual evaluation" here because the most important sense involved is that of touch or feel, although other senses such as sight are also involved to some extent. Because of its composite nature, feel is difficult to measure objectively and express numerically. One object of the present work was to find, if possible, certain tests or a combination of tests that would have high correlations with feel for this type of leather. Such correlations, of course, would not apply to all types of leather because the desired feel would vary with the use to be made of the leather and emphasis would be placed on one or another of the properties that enter into feel, depending on the demands of the user.

To obtain the desired information on feel, it was necessary to have the leather graded by the tanner; this was done by two tannery representatives on the leathers from the second experiment. Whole skivers were too large to handle easily, so 9- x 12-inch pieces were cut from the shoulder portion of each skiver (Fig. 1, area G). They were numbered in code to conceal identification. Grading for tannage, ignoring both color and any defects that were obviously not related to the sumac, was done by first sorting out all pieces that were commercially unacceptable. The remaining pieces were then divided into two groups according to quality, after which each group was further divided into two groups. Thus the pieces were sorted according to quality of tannage into five groups, group 5 being best and group 1 poorest.

The number of pieces in each group for each tannage was then counted, after which the average or mean grade for each lot was found by multiplying

TABLE I

Tactual Evaluation of Sumac-Tanned Sheepskin Skivers

Lot	Tanning Agent	GRADING FOR TANNAGE: By Tanner A Skivers in Grade* 5 No.	4 No.	3 No.	2 No.	1 No.	By Tanner B Skivers in Grade* 5 No.	4 No.	3 No.	2 No.	1 No.	Mean Grade for Tanner A	Mean Grade for Tanner B	Rank (Both Grades)	Grading for Surface Smoothness: Mean Grade	Rank
A	*R. copallina* leaves	8	3	0	3	1	2	1	5	4	3	3.9	2.7	3	3.4	5
B	*R. copallina* leaves	5	5	2	3	0	4	1	5	4	1	3.8	3.2	2	4.2	1
C	*R. coppallina* leaves	11	1	2	1	0	6	2	2	3	2	4.5	3.5	1	3.8	2
D	*R. glabra* leaflets	4	6	1	2	2	3	2	0	6	4	3.5	2.6	5	3.0	8
E	*R. glabra* leaves	4	3	0	7	1	1	2	4	0	8	3.1	2.2	9	2.6	10
F	*R. glabra* leaflets	2	5	3	3	2	0	4	3	3	5	3.1	2.4	7	2.2	11
G	*R. typhina* leaves	2	2	5	4	2	2	2	1	4	6	2.9	2.3	10	3.2	6
H	*R. typhina* leaflets	2	2	5	3	3	0	3	3	1	8	2.8	2.1	11	2.8	9
K	*R. typhina* leaves	2	2	6	2	3	3	2	1	4	5	2.9	2.6	8	3.7	3
L	*R. typhina* leaflets	7	1	3	1	3	5	1	2	3	4	3.5	3.0	4	3.5	4
M	*R. coriaria* leaves	1	4	5	4	1	1	4	4	1	5	3.0	2.7	6	3.0	7

*Grade 5 is best.

TABLE II

Analysis of Variance of Tanners Grades.

Source of Variation	Degrees of Freedom	Mean Square	F[1]
Between tanners	1	2.695	13.3**
Between species	3	.951	4.7*
Lots in species (error)	7	.202	5.0*
Interaction (tanners X lots)	10	.040	—
Species comparisons			
R. copallina versus others	1	2.837	14.0
Other comparisons	2	.008	0.0

[1]*Significant beyond 5 per cent point;
**Significant beyond 1 per cent point. Since "Lots in species" is significant when tested against "Interaction," it is the proper error term for testing other mean squares.

the number of pieces in each grade by the grade number, taking the sum of these products and dividing by 15. For example, for lot A (Table I), the mean grade was [(8 x 5) + (3 x 4) + (0 x 3) + (3 x 2) + (1 x 1)] /15=59/15=3.9.

For this grading, closely defined limits could not be established before the work started. Essentially each tanner developed his own grade limits during the sorting, attempting to adjust the limits so as to obtain approximately the same number of skivers in each grade. In this they were only partially successful. The numbers of skivers per grade, in decreasing grade order, were as follows: for Tanner A, 48, 34, 32, 33 and 18; for Tanner B, 27, 24, 30, 33 and 51. Tanner B was more severe in his judging than Tanner A, as shown by the greater number of skivers he placed in the lowest grade, and also by the fact that his average grade was 2.7 while that for Tanner A was 3.4. Tanner A considered only thoroughness of tanning, but Tanner B considered also "weight", a judgment based principally on thickness but influenced also by other properties, such as softness. Tanner A spent much more time than Tanner B in grading the leathers.

Table I shows the results, and an analysis of variance of the results is given in Table II.

There was a highly significant difference between tanners (Table II), reflecting their difference in grade limits. However, the low interaction between tanners and lots, with a mean square of 0.04 (Table II), and a highly significant correlation coefficient of 0.82 between their gradings show that they were in good agreement as to the relative value of the various lots.

The average species grades, based on the results of both tanners, were as follows: *Rhus copallina*, 3.60, *R. coriaria*, 2.85, *R. glabra*, 2.82 and *R typhina*, 2.76. The grade for *R. copallina* was markedly higher than those for the other species. In Table II, under species comparisons, the mean square for species has been divided into mean squares for single degrees of freedom as described in Chapter 15 of Snedecor[14]. A highly significant difference between *R. copallina* and the others is shown. The use of single degrees of freedom is, however, open to criticism in the present case, because the use of the comparison "copallina versus others" instead of other comparisons is based on the results themselves rather than on previous knowledge or other facts. Tukey[15] has recently proposed a method* for comparing individual means. By this method, there are no group boundaries, but *R. copallina* is a straggler; that is, it is significantly better than some of the other species at the 5 per cent level. There is no evidence of differences between the other species at this level. The evidence thus is strong that *R. copallina* produced better leather in this test than did the other species and that the latter did not differ among themselves.

There is no evidence that the tanners made a distinction based on leaves and leaflets, although the average grade for leaflets is a trifle higher than that for leaves. For an unknown reason, one lot of leaflets, Lot L, made much better leather than the corresponding lot of leaves, Lot K. This behavior of Lot L is surprising because it was prepared from Lot K by air elutriation, yet Lot H, which was prepared by the same process from Lot G, did not quite equal the latter.

Surface Smoothness. This property, one element of feel, was determined by moving the hand lightly across the grain surface of the leather pieces resting on a flat surface. The pieces were divided into five groups, and mean grade and rank were determined as described above for feel. Grading was done by three of the laboratory personnel. The results are given in the last two columns of Table I, and an analysis of variance is given in Table III.

There was a significant difference between species. The difference between graders was highly significant, but this probably was the result of different grade limits rather than disagreement as to the relative smoothness of the various lots. The coefficients of rank correlation between the lot rankings by the three graders were approximately 0.90. For each grader, Lot B was first, Lot C was second or third, Lot E was tenth, and Lot F was eleventh. There is evidence, therefore, that *R. copallina* produced the smoothest and *R. glabra* the roughest leather. There was no difference based on leaves and leaflets.

Surface smoothness would be expected to be one element in feel. Tanner B favored leather with a smooth surface. The correlation coefficient, r, between

*Briefly the steps in Tukey's method are as follows:

(1) Arrange the means in increasing numerical order.

(2) Calculate, at a given level of significance (usually 5%), the least significant difference (LSD) or the difference which would have been significant if there had been but two varieties; consider any gap between adjacent means that is greater than LSD as a group boundary.

(3) Within each group of 3 or more values, test for stragglers, that is, values which straggle too much from the group mean.

(4) After separating stragglers, test each group of 3 or more for excess variability by usual analysis of variance methods and the F-test.

The final significance level is uncertain. Although, for example, the 5 per cent level may have been chosen, after the successive operations have been applied the level will be higher.

TABLE III

Analysis of Variance of Smoothness Grades.

Source of Variation	Degrees of Freedom		Mean Square[1]	F[1,2]
Lots (L)	10		1.007 (a)	39.8*** a/e
Species (S)		3	2.288 (b)	5.0* b/c
Lots in species (Ls)		7	.458 (c)	16.7** c/g
Graders (G)	2		.319 (d)	12.6*** d/e
Lots X graders (LG)	20		.025 (e)	—
Species X graders (SG)		6	.020 (f)	0.7 f/g
Lots in species X graders (LsG)		14	.027 (g)	—

[1] Letters are for identification purposes only.

[2] * Significant beyond 5 per cent point; **significant beyond 1 per cent point; ***Significant beyond 0.1 per cent point.

his grades and those for smoothness had the highly significant value of 0.80. For Tanner A the value of r was 0.57. This non-significant value does not necessarily mean that he attached no importance to smoothness; rather he probably considered it subordinate to tannage. Other factors being equal, it seems reasonable to suppose that a tanner would prefer a smooth rather than a harsh surface for the type of leather considered here.

Methods of Sampling and Testing

Sampling of the leather from the first tannery experiment will not be described as only a limited number of tests were made. For the second tannery experiment, the methods of sampling and testing were the following:

The right bend area of each skiver was used, various test pieces being cut as shown in Figure I. Replicate test pieces from the same skiver were taken for some tests. No study was made of variability due to position within the skiver; whenever replicate test pieces were taken they were contiguous. In cutting out the test pieces, most measurements were made in the English system, but nearly all the physical testing measurements were made in the metric system; all results have been reported in the latter system. Except as noted, all specimens were conditioned and tested in a room regulated at 70°F. and 65 per cent relative humidity.

Weight per unit area, thickness, and apparent density were measured on piece WXYZ (Fig. 1) before cutting out the various test specimens. The pieces were 10 inches wide and from 14 to 18 inches long, depending on the size of the individual skivers.

Real density was measured on pieces D1 and D2 (Figure 1) by the method of Galley and Tapp as modified by Kanagy and Wallace [9].

Tensile strength of the original leather and of leather after acid or heat deterioration was determined on 12 strips per skiver, cut as shown in Figure

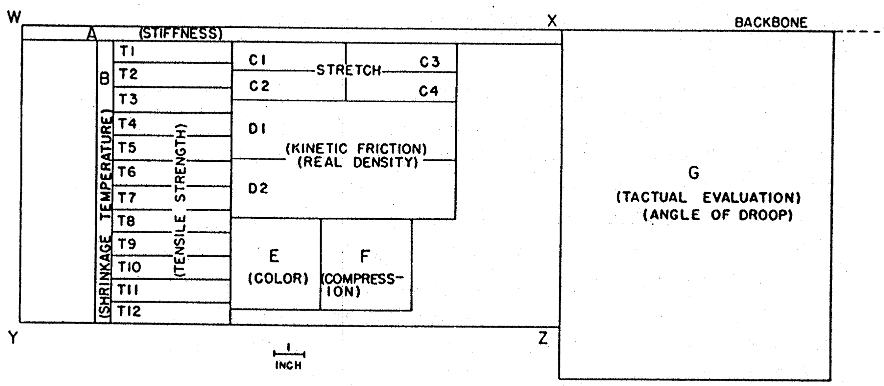

FIGURE I—Location of test specimens.

1. The individual test pieces, T1 to T12 inclusive, were cut with a die similar to the official A.L.C.A. die in shape but only 8 centimeters long, with a test portion 1 centimeter wide and 2.5 centimeters long. Tensile strength of the original leather was found by breaking all strips except 3, 6, 7, and 10 from 9 skivers of each lot. Strips 3, 6, 7 and 10 were used for a *heat deterioration* study. These strips were conditioned at 73° F. and 50 per cent relative humidity rather than at the 70° F. and 65 per cent relative humidity used for all other test specimens. The tensile specimens from the remaining 6 skivers of each lot were used for a *gas chamber deterioration*[7] study, strips 1, 4, 9, and 12 being used as untreated controls and strips 2, 5, 8, and 11 being exposed in the gas chamber. (The remaining 4 strips are not reported on here.)

Stretch parallel to the backbone was measured on 4 strips from each skiver at loads of 10.6 and 21.1 kilograms per square centimeter (150 and 300 pounds per square inch); the loads were applied in successions, and stretch was measured by the official method.

Stiffness was measured by three methods. In one, the angle of droop was measured with a crude model of the Peirce Flexometer[13]. This apparatus, designed for textiles, has also been used for leather by Conabere and Hall[5]. For this test, the 9- x 12-inch pieces (G, Figure 1) were placed on a flat, horizontal plate with exactly 5 inches of the leather projecting over the edge of the plate. The angle between the overhanging edge of the leather and the plane of the plate was measured in degrees, after which bending length, c, flexural rigidity, G, and bending modulus, q, were calculated by the following formulae:

$$c=1(\cos 0.5\ \theta/8 \tan\ \theta)^{1/3}$$
$$G=w\ c^3$$
$$q=12\ G/d^3$$

where l is length overhanging in centimeters, θ is angle of droop in degrees, w is weight of leather in grams per sq. cm., and d is thickness of leather in centimeters.

Stiffness was also measured with the official A.L.C.A. apparatus for flexibility except that a 0.5 inch-pound machine was used with a load of 0.005 inch-pounds. For this test, strip A (Fig. 1) was divided into 8 equal parts for 8 replicate determinations per skiver. The strips were 0.5 inch wide, the span length was 0.5 inch, and the bend was made so the grain was convex. Load scale readings were taken when the sample had bent first 6 degrees, then 9 degrees. Preliminary tests indicated that if the angle of bend was more than 10 or 11 degrees the leather was noticeably permanently deformed. From the data so obtained, stiffness in flexure, E, was calculated by the following formula[1]:

$$E=\frac{4\,s\,M\,L}{100\,w\,r\,d^3}$$

where s is span length, M is the load applied to the pendulum system, L is the load scale reading, w is specimen width, r is the angular deflection in radians, and d is specimen thickness.

From the previous report[4], data were available on stiffness measured on the whole skiver by folding it perpendicular to the backbone, halfway between head and tail, then measuring the height of the fold in millimeters by means of a cathetometer. This value is called here "stiffness by fold."

Set was measured on the A.L.C.A. apparatus immediately after stiffness was measured at the 9-degree bend. The pendulum weight was increased from 0.005 to 0.025 inch-pounds; the angle of bend was increased to 80° and held at that point for 20 seconds, then the load was removed by means of the hand crank and the angle of set in degrees was noted at zero load.

Compressibility or hardness was measured with the official dead-weight type of thickness gage having a foot three-eighths of an inch in diameter. The original thickness under a load of 200 grams was noted first, then the thickness under a load of 10 kilograms. The latter reading was taken 5 minutes after application of the load, when the reading was practically constant. Compressibility is decrease in thickness as percentage of original thickness. Because the leathers were thin, 5 pieces, each from a different skiver but all from the same lot, were combined for each measurement. There were, therefore, only 3 values per lot instead of 15.

Kinetic friction was measured on the Dreby friction meter[6]; two 2- x 7.5-inch test pieces (D1 and D2, Fig. 1) from the same skiver were placed grain to grain and loaded with a 21-ounce weight.

Shrinkage temperature was measured by the A.L.C.A. method on specimens from 5 skivers of each lot, both before and after washing to remove most of the soluble chloride.

Resistance to deterioration at high temperatures was measured by the official A.L.C.A. method, except that the exposure time was 2 weeks instead of 1 because a preliminary test showed no deterioration in 1 week.

For *chemical analysis*, a sample of each lot was prepared by combining undamaged parts of tested specimens and the bend blocks left after test specimens were taken.

Color was measured on the ground leaves as used for tanning and on the tanned skivers both before and after exposure to light, but only data on leaves and unexposed skivers are presented here.

The leaf material had been ground in a hammermill to pass a $^1/_{64}$ inch screen and was, therefore, lighter in color than whole leaf and much lighter than the upper surface of the leaf blade as seen on the living plant. This was especially true for *Rhus glabra* and *R. typhina* leaves which have large pithy petioles and rachises.

The skiver samples were taken at position E (Fig. 1), this position being shifted as necessary to avoid spots or surface irregularities that would have low reflectance. Only two skivers per lot were measured because of the labor and time involved in integrating the data.

The primary measurements were curves showing per cent reflectance (relative to magnesium oxide) versus wave length for the visible spectrum, obtained with a General Electric recording spectrophotometer. From the curves, tristimulus values, based on the I.C.I.* standard observer and standard illuminant C, were determined with a General Electric tristimulus integrator, reading 30 selected ordinates for leaf samples and 10 for skivers. Trichromatic coefficients and "lightness" (integrated reflectance) were then calculated, after which dominant wave length and excitation purity were found from the charts given by Hardy[8]. Hue, value and chroma of the Munsell notation[10, 11], which is based on visual appearance, were calculated from charts given by Newhall, Nickerson and Judd[12].

In analyzing the data, statistical calculations were made by methods described by Snedecor[14]. As a rule, the conventional 5 per cent point was chosen as the significance level. Certain calculations were not so satisfactory as one would wish because the data were meager and unsymmetrical in some respects. Mean squares between and within lots and correlation coefficients between lots and physical properties were satisfactory. Division of the mean square for lots into mean squares for species and lots within species was less helpful, first because of possible confounding of species with other uncontrolled factors, but especially because of the small and unequal number of lots for the different species. (It was possible to obtain only one lot of Sicilian sumac at the time.) Distinctions between materials (leaves and leaflets) and between different species were least satisfactory; however, certain calculations were made in order to throw as much light as possible on species

*International Commission on Illumination (Hardy[8]).

differences since they were of principal interest. For comparisons such as those between species, Fisher has proposed use of the discriminant function (for references and an application, see Baten and De Witt[2]). This method was too laborious and unrewarding for the unsymmetrical data presented here, but its use should be considered when experiments of this general nature are planned.

Results of Chemical and Physical Tests

Results on leather from the first tannery experiment are given in Table IV. These data are used only to supplement those from the second tannery experiment because the number of tests was limited and also because the skivers used for packs No. 1 and No. 2 were not strictly comparable with those for packs No. 3 and No. 4.

TABLE IV

Tests and Analyses of Leathers from the Four Packs of Skivers Tanned in 1942-3

Pack No. Material	1 Rhus coriaria leaves	2 Rhus copallina leaves	3 Rhus glabra leaflets	4 Rhus glabra leaves
Physical tests				
Tensile strength, kg/cm$_2$	47.2	39.0	49.0	42.3
Stretch at break, per cent	9.4	16.5	8.7	8.8
Thickness, cm.	.07	.08	.06	.06
Density, apparent, gm/cc	.44	.40	.42	.42
Density, real, gm/cc	1.50	1.45	1.53	1.51
Color*, per cent	44.3	47.9	48.9	46.0
Chemical analysis (oven-dry basis)				
Petroleum ether extract, per cent	2.8	3.7	1.9	2.1
Insoluble ash, per cent	2.3	1.8	1.7	2.1
Water solubles, per cent	4.5	4.4	6.0	5.8
Hide substance, per cent	59.4	59.2	55.6	54.3
Combined tannin, per cent	31.0	30.9	34.8	35.7

*Reflectance relative to magnesium oxide; measured on a photoelectric filter photometer for green light (546 millimicrons).

Chemical Analyses. Analyses of the leathers from the second tannery experiment are given in Table V. They show no striking differences between the various lots. We will consider only combined tannin and degree of tannage, as they measure the tanning action of the different lots and species of sumac.

The lots may be divided into 6 groups according to species and materials (leaves and leafets). The analysis of variance of grouped data, Table VI, shows significant differences between groups in combined tannin and degree of tannage, but of course does not indicate whether the differences are due to species or materials or both.

TABLE V

Chemical Analyses of Sumac-Tanned Leathers in the 1944 Experiments

Lot	Tanning Agent	Total Ash	Insoluble Ash	Petroleum Ether Extract	Water Soluble Matter	Uncombined Tannin	Hide Substance	Combined Tannin	Degree of Tannage
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent*
A	*Rhus copallina* leaves	7.3	2.8	1.9	11.1	2.8	50.1	34.1	68.1
B	*Rhus copallina* leaves	6.7	2.5	1.5	10.8	3.0	49.4	35.8	72.5
C	*Rhus copallina* leaves	7.1	2.6	1.9	11.2	2.3	49.7	34.6	69.6
D	*Rhus glabra* leaflets	6.5	2.2	2.0	11.4	3.4	51.9	32.5	62.6
E	*Rhus glabra* leaves	6.8	2.3	2.0	11.4	3.2	51.4	32.9	64.0
F	*Rhus glabra* leaflets	6.3	1.7	2.2	11.7	3.3	52.3	32.1	61.4
G	*Rhus typhina* leaves	7.5	2.9	2.2	11.1	3.0	50.5	33.3	65.9
H	*Rhus typhina* leaflets	6.8	2.3	2.0	11.1	3.1	52.3	32.4	62.0
K	*Rhus typhina* leaves	7.8	3.0	2.0	11.2	3.0	49.8	34.0	68.3
L	*Rhus typhina* leaflets	7.3	2.7	2.1	11.3	3.1	51.0	32.9	64.5
M	*Rhus coriaria* leaves	8.2	3.7	2.3	11.2	3.1	49.8	33.0	66.3

*Degree of tannage is combined tannin as percentage of hide substance

TABLE VI

Analysis of Variance of Combined Tannin and Degree of Tannage for Groups

Source of Variation	Degrees of Freedom	Combined Tannin Mean Square	F	Degree of Tannage Mean Square	F
Groups	5	20.64	6.2*	2.05	5.2*
Lots within groups	5	3.35	–	.40	–

*Significant beyond 5 per cent point.

To examine the data further, a procedure was adopted which will be described in some detail for degree of tannage as it was applied also to data from the other tests. This method was necessary because there were unequal numbers of lots per group and because two values for leaflets were missing. To obtain an orthogonal set of data, degree of tannage values with zero interaction (species x materials) were estimated for *R. coriaria* and *R. copallina* leaflets as follows: The degree of tannage value for *R. glabra* leaflets was 2.0 less than the value for leaves, whereas for *R. typhina* the difference was 3.9. The average difference of 3.0 was subtracted from the two values for leaves *R. coriaria* and *R. copallina*, 66.3 and 70.1, to obtain the estimates of 63.3 and 67.1 respectively, shown in Table VII for leaflets.

An analysis of variance was then made as usual, except that the error term of 2.1 was calculated from the within-group variation of Table VI. The degrees of tannage in Table VII are averages (in leaf, leaflets, species order) of values for 1, 2, 2, 2, 1, 3 lots. The harmonic mean (K_o) of these is 1.56,

TABLE VII

Degree of Tannage. Species Averages.

Species of *Rhus*	Degree of Tannage for Leaves Per cent	Leaflets Per cent
R. glabra	64.0	62.0
R. typhina	67.1	63.2
R. *coriaria*	66.3	(63.3)*
R. copallina	70.1	(67.1)*

*Missing plot estimates with interactions zero.

derived from the equation: $1/K_0=1/6\ (1+{}^1/_2+{}^1/_2+{}^1/_2+1+{}^1/_3)$. The error term of 2.1 (Table VIII) is 3.35 (from Table VI) divided by 1.56. The F values in Table VIII show that there was a difference in degree of tannage for materials and Table VII shows that leaflets were lower than leaves in this value. Combined tannin was also lower in the leaflets, although the difference was significant only at about the 8 per cent point.

TABLE VIII

Analysis of Variance of Degree of Tannage Data.

Source of Variation	Degrees of Freedom	Mean Square	F
Species	3	11.0	5.2[1]
Materials	1	17.7	8.3[2]
Materials x species	1[3]	.9	0.4
Error[4]	5	2.1	—
Species comparisons			
copallina vs. others	1	27.5	12.9
glabra vs. *typhina* and *coriaria*	1	5.2	2.4
typhina vs. *coriaria*	1	0.1	0.1

[1] Significant at about 5.5 per cent point.
[2] Significant beyond 5 per cent point.
[3] 2 degrees of freedom lost because of 2 missing plots.
[4] See text.

The mean square for species was nearly significant at the 5 per cent point. In Table VIII, one of several possible sets of species comparisons is listed, this particular set having been chosen because it showed most pronounced differences. Since, as was pointed out earlier, the choice was based on the results, the probability level is unknown; however, it does indicate a difference between *R. copallina* and the other species. By Tukey's method there is a group boundary betwen *R. copallina* and the others at the 5 per cent point for combined tannin and at about the 7 per cent point for degree of tannage.

There is thus good evidence that *R. copallina* produces higher combined tannin and degree of tannage than the other three species and that the others do not differ among themselves.

The question might arise as to the possible effect of ratio of hide substance to tannin in the vats during tanning, since this ratio could not be controlled exactly nor determined accurately because the pickled skivers could be sampled only at the flanks. The results showed no correlation between this ratio and degree of tannage.

Color data. Color data are given in Table IX and typical reflectance curves in Figures II and III.

TABLE IX

Colorimetric Analysis (I.C.I. Coordinate System and Illuminant C) and Munsell Notation for Ground Sumac Leaves and for Sheepskin Skivers Tanned with the Leaves

Material and Lot Designation	Trichromatic Coefficients x	y	Lightness Y	Dominant Wave Length	Excitation Purity	Munsell Hue	Munsell Value/Chroma
			Per cent	Millimicrons	Per cent		
Ground leaves							
A	.3721	.3997	22.9	573.6	39.0	8.2Y	5.3/3.6
B	.3759	.3978	28.8	574.6	39.4	6.6Y	5.9/3.9
C	.3836	.3770	29.2	580.2	34.0	0.6Y	5.9/3.9
D	.3882	.3564	14.2	586.8	31.7	5.1YR	4.3/3.7
E	.3614	.3814	28.9	574.3	31.2	6.8Y	5.9/3.1
F	.3760	.4003	22.2	574.3	40.2	7.4Y	5.3/3.6
G	.3630	.3881	26.8	573.4	33.5	8.2Y	5.7/3.3
H	.3736	.4049	20.6	573.1	40.7	9.0Y	5.1/3.6
K	.3665	.3906	26.4	573.9	35.0	7.6Y	5.7/3.4
L	.3719	.3992	22.8	573.6	38.6	8.2Y	5.3/3.6
M	.3712	.3830	29.8	576.3	34.3	4.2Y	6.0/3.4
*Sheepskin leather**							
A	.3485	.3536	48.3	578.0	20.4	1.7Y	7.4/2.4
B	.3473	.3492	51.6	579.2	18.8	0.3Y	7.6/2.3
C	.3555	.3570	49.1	579.1	23.1	0.7Y	7.4/2.8
D	.3460	.3479	45.9	579.2	18.0	0.4Y	7.2/2.1
E	.3474	.3540	48.4	577.3	20.1	2.3Y	7.4/2.3
F	.3442	.3519	49.4	576.9	18.7	2.6Y	7.4/2.1
G	.3487	.3538	45.8	578.0	20.3	1.7Y	7.2/2.4
H	.3461	.3517	48.7	577.8	19.2	2.2Y	7.4/2.2
K	.3437	.3493	47.6	577.7	17.8	1.8Y	7.3/2.1
L	.3454	.3530	49.0	577.0	19.3	2.6Y	7.4/2.2
M	.3464	.3460	50.4	580.0	17.7	9.3YR	7.5/2.2
Sheepskin leather, species averages							
ABC (*Rhus copallina*)			49.7	578.8	20.8	0.9Y	7.47/2.5
DEF (*R. glabra*)			47.9	577.8	18.9	1.8Y	7.33/2.2
GHKL (*R. typhina*)			47.8	577.6	19.2	2.1Y	7.32/2.2
M (*R. coriaria*)			50.4	580.0	17.7	9.3YR	7.50/2.2

*All values are averages for duplicate skivers.

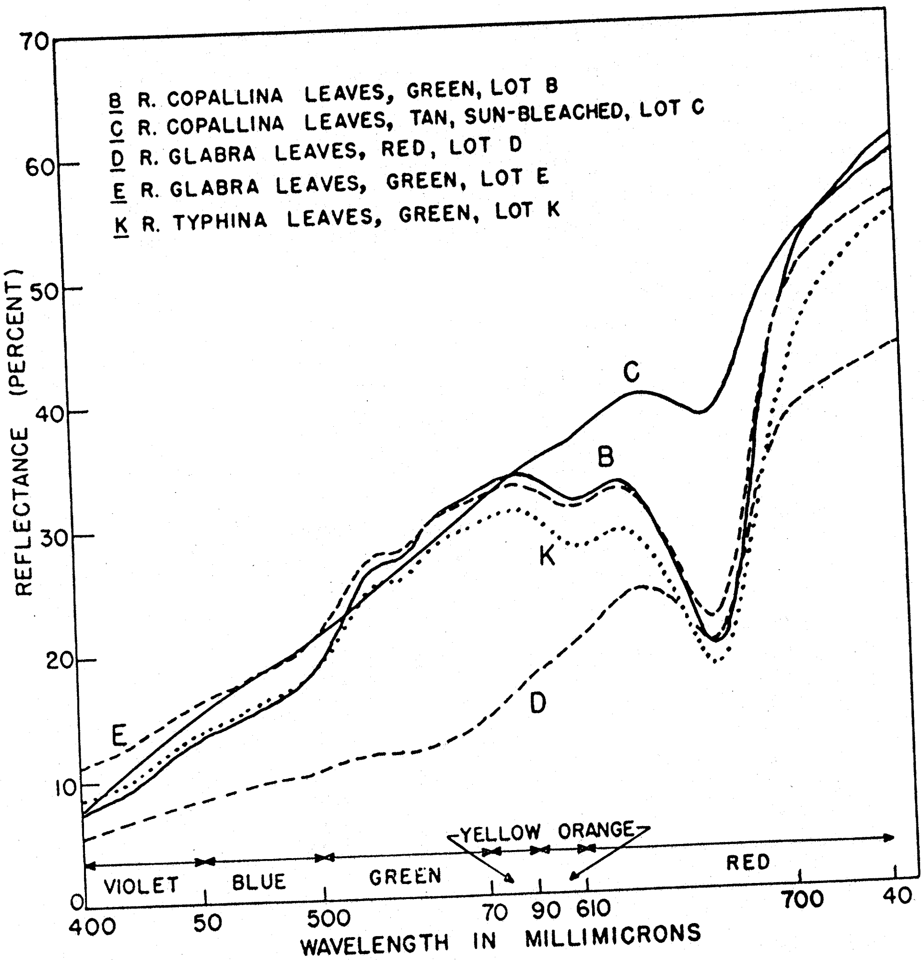

FIGURE II—Spectral reflectance curves of 5 samples of sumac leaves. Measurements are relative to magnesium oxide.

Curves B, E, and K (Figure II) are for leaves that were green when picked. They show a dip centered at 670 millimicrons due to absorption by chlorophyll or a derivative. The curve for sun-bleached leaves, curve C, is similar to that for Lot B, except that the absorption by chlorophyll is much less. Red leaves*, Lot D, have a low reflectance, except for the longer wave lengths.

In Figure III are shown spectral reflectance curves for three lots of leaves and the corresponding curves for 2 leathers tanned with each. The curves for leathers are higher than those for leaves, indicating that the leathers are whiter and lighter. For leathers tanned with the same lots of leaves, the curves differ considerably, but it is well known that leather color (for ex-

*Actually the ground leaves contained much green material, as only the upper surface of the leaves was red.

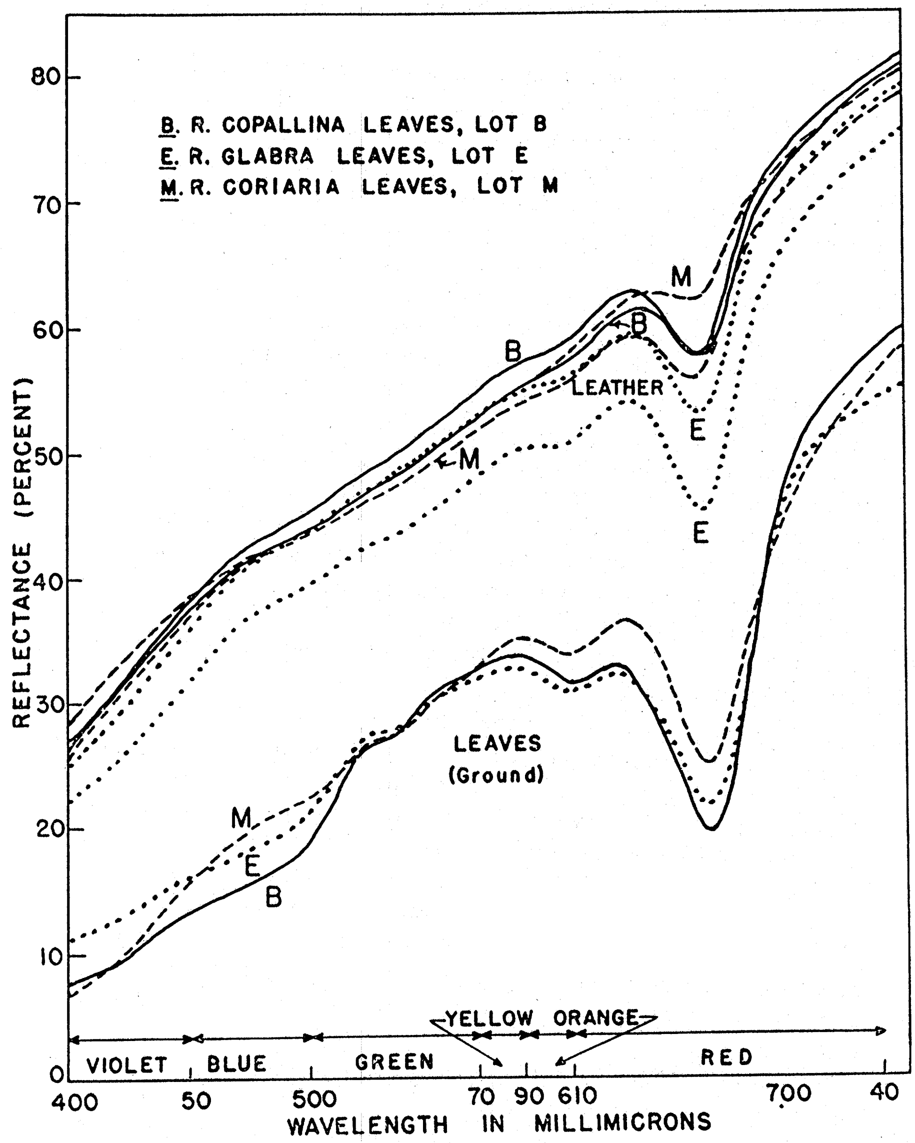

FIGURE III—Spectral reflectance curves of sumac leaves and leathers. Measurements are relative to magnesium oxide.

tremely light colors) is determined by the skin as well as by the tanning material and varies not only between skins but also between locations on the same skin.

The colorimetric analysis, columns 2 to 6 of Table IX, gives complete specifications in the I.C.I. system for colors of the leaves and leathers. The remaining columns give specifications in hue, value and chroma of the Munsell system.

Munsell hue corresponds to dominant wave length in the I.C.I. system. Y denotes yellow and YR, yellow red, but 10.0 YR is the same as 0.0Y, so that 8.2 Y, for example, might be called 18.2 YR. All hues in Table IX, therefore, could be expressed as YR by adding 10 to each Y hue. Value, corresponding to lightness, is based on a scale of 10 steps from black to white, the steps being equal as judged by eye and, therefore, logarithmic. Chroma corresponds to excitation purity. A decrease in chroma may be considered to be a dilution of a saturated hue with white. By visual comparison under usual conditions at about /5 chroma, one can distinguish steps of 0.5 in hue, 0.1 in value and 0.3 in chroma. With a good instrument, smaller differences may be seen, particularly in value. Lightness is the most important attribute of color for these leathers, as they are all near white.

The previous publication[4] gave reflectance values for green light (546 millimicrons) for leaves and leathers. Those values were lower by 2 to 6 per cent for leaves and by an average of about 1 per cent for leathers than the lightness values given in Table IX. Correlations between lightness and reflectance of green light were good, the coefficient, r, for leaves being 0.96 and for leather, 0.86. For low chroma materials, such as these leathers and ground leaves, measurement of reflectance for green light should usually be a sufficient evaluation of their color.

Of principal interest here is the relation between color of leaves and color of leather. The correlation coefficients between leaf and leather color for lightness, dominant wave length, and purity were 0.50, 0.55, and -0.10, respectively. The first two are just below significance at the 5 per cent point, as a value of 0.58 is required. In other words, for this test involving only 2 skivers per lot, leather color was not closely related to leaf color. On the other hand, in the previous article[4] reflectance values for green light were given for ground leaves (Table II of reference 4) and for each lot of leather based on from 64 to 69 skivers per lot (Table IX of reference 4). The correlation coefficient between those reflectances was 0.84, a highly significant value.

A high correlation does not indicate similarity of color, however; it indicates only that the various lots of leaves behaved consistently as regards color of leather they produced. The lot showing least difference between leaves and leather in hue or dominant wave length was the sun-bleached leaves, Lot C, for which the leaf hue was 0.6 Y and the leather hue was 0.7 Y. The reason this difference is so small appears to be that leaves are greener than skivers because of chlorophyll or one of its derivatives; chlorophyll is readily bleached by light; and removal of this chlorophyll from the leaves by bleaching decreases or eliminates the difference in hue between leaves and leather. This chlorophyll is only loosely bound by skin, and much of that taken up during tanning

TABLE X

Results of Physical Tests on Sumac-Tanned Sheepskin Skivers
Averages for lots or species based on 15 skivers per lot

LOT	Tanning Agents	Weight per Unit Area	Thickness	Apparent Density	Real Density	Tensile Strength	Stretch at Load of 10.6 kg/cm²	Bending Length c	Flexural Rigidity G	Bending Modulus q	Stiffness in Flexure	Set	Com-pressibility	Coefficient of Kinetic Friction	Shrinkage Temperature	Acid Deterioration Loss in Tensile Strength	Heat Deterioration Loss in Tensile Strength
LOT	Species of *Rhus*, material and source	mg/cm²	microns	g/cm³	g/cm³	kg/cm²	%	cm.	gm/cm	kg/cm²	kg/cm²	angular°	%		°C.	%	%
	Rhus copallina																
A	leaves from Wells Tannery, Pa.	29.6	720	0.412	1.502	35.4	5.60	5.85	5.98	251	129.8	22.8	25.1	34.6	80.1	43.8	3.6
B	leaves and leaflets from Beltsville, Md.	30.9	762	.406	1.537	30.0	5.67	5.56	4.98	196	137.1	22.4	25.3	34.0	80.0	44.3	6.4
C	leaves from Laurel, Md.	31.6	768	.411	1.535	32.2	5.45	6.52	8.91	293	151.7	22.3	23.4	33.1	79.7	43.2	9.5
	Rhus glabra																
D	leaflets from Wells Tannery, Pa.	29.2	705	.415	1.539	39.0	4.20	6.88	9.66	405	231.2	22.9	24.8	33.6	79.0	43.0	7.9
E	leaves from Hagerstown, Md.	28.8	654	.440	1.583	44.4	2.90	6.74	8.86	392	276.6	21.4	20.4	31.6	79.1	48.0	2.8
F	leaflets from Hagerstown, Md.	30.1	700	.431	1.519	42.5	3.40	6.92	10.79	389	247.0	21.9	21.7	31.4	78.8	52.4	2.4
	Rhus typhina																
G	leaves from Wells Tannery, Pa.	31.2	702	.445	1.549	35.5	3.06	7.07	10.67	478	236.4	21.6	20.5	31.8	78.1	50.0	-0.2
H	leaflets from Wells Tannery, Pa.	29.0	667	.437	1.550	35.2	3.23	6.65	8.53	407	276.6	21.6	23.2	31.8	78.7	50.6	3.1
K	leaves from Hagerstown, Md.	30.6	696	.441	1.554	38.7	2.19	6.75	9.42	432	322.6	21.4	20.1	30.4	78.5	40.2	2.8
L	leaflets from Hagerstown, Md.	29.8	678	.440	1.600	34.1	3.00	6.85	9.32	490	284.6	20.8	21.2	30.8	78.5	45.5	0.2
ABC	*Rhus copallina*	30.7	750	.410	1.525	32.5	5.57	5.97	6.62	247	139.5	22.5	24.6	33.9	80.0	43.8	6.5
DEF	*Rhus glabra*	29.3	686	.429	1.547	42.0	3.50	6.85	9.77	395	251.6	22.1	22.3	32.2	79.0	47.8	4.4
GHKL	*Rhus typhina*	30.2	686	.441	1.563	36.1	2.87	6.83	9.49	452	280.0	21.4	21.3	31.2	78.4	46.6	1.5
M	*Rhus coriaria*	29.4	690	.427	1.532	28.6	4.25	6.53	8.17	359	217.7	20.8	24.4	30.8	79.1	40.8	3.4

is removed during degreasing, washing, and fatliquoring. Removal of chlorophyll or its derivatives from the leaves before tanning or from the leather by washing or by bleaching in light will result in leather of a more uniform, stable color.

Physical test data. Average results from the various physical tests, except those for color, are shown in Table X. Table XI gives an analysis of variance of the data for each test.

TABLE XI

Analysis of Variance of Physical Test Data.

Physical Test	Factor	Mean Square[1] for Variation Between: Species[2]	Lots[3] within Species	Skivers[4] within Lots	Replicates within Skivers	Degrees of Freedom for Skivers within Lots	Degrees of Freedom for Replicates within Skivers
Weight per unit area	1	16	12	13	-	154	—
Thickness	10^{-2}	438*	79	72	-	154	—
Apparent density	10^4	83**	8	5	-	154	—
Real density	10^4	136	101**	19	-	154	—
Tensile strength	10^{-1}	474**	43	77**	5	88	693
Stretch	1	265**	13	12**	2	154	495
Bending length	10^2	783*	128*	56	-	154	—
Flexural rigidity	1	95[5]	27*	12	-	154	—
Bending modulus	10^{-3}	372**	20	16	-	154	—
Stiffness in flexure	10^{-3}	1444**	87	67**	6	154	1155
Set	1	148*	28	36**	5	154	1155
Compressibility	1	22	8	2	-	22	—
Kinetic friction	1	147*	25**	9**	5	154	165
Shrinkage temperature	10	67**	2	6	-	44	—
Acid deterioration	1	101	98	67[6]	-	53	—
Heat deterioration	1	134	116*	51	-	88	—

1. Mean squares have been multiplied by the factors shown in column 2 and rounded to avoid fractions.

2. Degrees of freedom 3: *significant beyond 5 per cent point, **significant beyond 1 per cent point based on mean squares for lots within species.

3. Degrees of freedom 7: *significant beyond 5 per cent point, **significant beyond 1 per cent point based on mean squares for skivers within lots.

4. **Significant beyond 1 per cent point based on mean squares for replicates within skivers.

5. Significant at approximately the 8 per cent point.

6. After removal of mean square of 2173 with 2 degrees of freedom for position in gas chamber.

These data are considered from more than one point of view. First, there is the question as to whether the results of any test are correlated with those of other tests; in other words, whether any two tests appear to measure the same property or which tests measure unrelated properties. The correlation between physical properties and chemical composition is also involved here. The next point to consider is associations and relations between physical test data and feel as determined by the tanner to find what qualities he considers important and to establish criteria for high-quality leather. Finally, species differences will be examined to determine which species is capable of producing the best leather, this information being of value to collectors or cultivators of sumac. The mean square values for variation between skivers and between replicates in Table XI measure variability from these sources for skiver leather. These mean squares will be of value for estimating variability when planning experiments on this type of leather. As the mean square for variation between skivers was always highly significant compared with that between replicates, there was little or no advantage in taking more than one test specimen per skiver.

Before discussing correlations, some supplementary information on certain tests will be given.

As was pointed out previously, stretch was measured under two different loads, one of 10.6 kilograms per square centimeter and the other of 21.1. Those at the lower load are given in Table X. The two sets of results were consistent, the coefficient of correlation between the two being 0.93, but at the higher load variability was greater, probably because this was near the breaking load for many specimens.

Stiffness in flexure values were essentially the same whether the angle of bend was 6° or 9°; only results for the 6° bend are given in Table X. Based on results from 4 skivers per lot, the average value for the 6° bend was 233.0 kilograms per square centimeter, and for the 9° bend, 223.5. The coefficients of variation, within skivers, for the various lots ranged from 25 to 42 per cent for the former and from 24 to 40 per cent for the latter.

The shrinkage temperature measurements given in Table X are for specimens washed to remove most of the salt. Even though the actual differences between species are small, the mean square is highly significant. For unwashed specimens, the average shrinkage temperatures for *Rhus copallina*, *R. glabra*, *R. typhina* and *R. coriaria* leathers were 77.6°, 76.3°, 75.2° and 76.1°, respectively, but these values do not differ statistically at the 5 per cent point because the variance is so great.

TABLE XII

Loss in Strength, Change in pH, and Soluble Nitrogen in Leather Exposed in Gas Chamber

Tanning Agent	Tensile Strength Loss	pH of Original Leather	pH Decrease during Exposure	Water-Soluble Nitrogen in Exposed Leather	Sodium Carbonate Soluble Nitrogen in Exposed Leather
	Per cent			Per cent	Per cent
Rhus coriaria	40.8	3.15	0.72	0.79	3.47
Rhus copallina	43.8	3.20	0.83	0.66	2.77
Rhus typhina	46.6	3.16	0.79	1.06	3.84
Rhus glabra	47.8	3.16	0.82	1.06	4.10

For acid deterioration studies in the gas chamber, an exposure of either 12 or 18 weeks is usual, but for these leathers an exposure of 45 weeks was required to get a 40 or 50 per cent loss in strength. This long time was made necessary both by the natural resistance of sumac leather and also by the presence of approximately 4.7 per cent of sodium chloride, which retards deterioration by sulfur dioxide [3].

Additional data on these deteriorated leathers are given in Table XII.

Correlations Between Properties

Associations between the results of the various physical tests are shown in Tables XIII and XIV, by the correlation coefficients, r. The r values were calculated from lot averages, not from results on individual skivers; they, therefore, have 9 degrees of freedom. The limitations of correlation coefficients should be kept in mind and also the fact that these correlations are for one special type of leather made from a homogeneous lot of raw skins, and therefore, may not hold for all other types of leather.

TABLE XIII

Correlation Coefficients for Stiffness Properties[1]

	Stiffness by fold	Stiffness in flexure	Bending modulus	Bending length
Stiffness in flexure	+ .91**[2]			
Bending modulus	+ .87**	+ .86**		
Bending length	+ .83**	+ .75**	+ .91**	
Flexural rigidity	+ .76**	+ .66*[3]	+ .84**	+ .97**

[1]. The coefficients are arranged in the form of table often used on maps for showing distances between cities. As an example, the coefficient for stiffness by fold and bending length is +0.83.

[2]. **Significant beyond 1 per cent point; degrees of freedom, 9.

[3]. *Significant beyond 5 per cent point.

Correlations for the various stiffness properties are given in Table XIII. All values, except one, are highly significant. Stiffness in flexure and bending modulus would be expected to be closely related, since they are based on two methods for measuring the same physical property and both have been calculated to unit thickness of leather. The r value, 0.86, is high, considering the fact that the test specimens for the two tests were cut from different locations in the skiver and in different directions and were different in size.

Correlations between other properties are given in Table XIV. For completeness, all coefficients are shown, but a high correlation does not necesarily mean that the two properties under comparison are dependent on each other; the association may be due to a common factor. For example, thickness and shrinkage temperature were significantly associated ($r=.64$), but this may have been because both were increased by an increase in a third factor, such as

TABLE XIV

Correlation Coefficients for Chemical and Physical Properties

	Degree of tannage	Comb. tannin	Thickness	Shrink. temp.	Stretch	Stiff. in flexure	Set	Compressibility	Coeff. of friction	Apparent density	Real density
Comb. tannin	+.98**										
Thickness	+.75**	+.80**									
Shrink. temp.	+.59	+.65*	+.64*								
Stretch	+.57	+.62*	+.79**	+.90**							
Stiff. in flexure	-.60*	-.63*	-.80**	-.85**	-.97**						
Set	+.22	+.34	+.61*	+.62**	+.66*	-.65*					
Compressibility	+.31	+.34	+.52	+.75**	+.86**	-.77**	+.59				
Coeff. of friction	+.38	+.49	+.63*	+.78**	+.84*	-.84**	+.90**	+.75**			
Apparent density	-.52	-.58	-.79**	-.88**	-.95**	+.87**	-.76**	-.87**	-.84**		
Real density	-.21	-.21	-.52	-.52	-.62*	+.65*	-.62*	-.62*	-.56	+.62*	
Tensile strength	-.59	-.53	-.51	-.36	-.57	+.52	+.09	-.58	-.19	+.45	+.19

*Significant beyond 5 per cent point.
**Significant beyond 1 per cent point.

combined tannin, rather than that thickness influenced the shrinkage temperature measurement. This is usually referred to as spurious correlation. Only correlations that appear to be of primary interest are discussed here.

Based on statistical significance at the 5 per cent point, an increase in combined tannin was coupled with increases in thickness, stretch, flexibility (decreased stiffness) and shrinkage temperature. An increase in degree of tannage was associated only with increases in thickness and flexibility, the fewer correlations being caused by the greater variance of degree of tannage.

Thickness, stretch, stiffness and apparent density were highly associated; the last two decreased as the first two increased or vice versa. Stretch, stiffness and apparent density were so closely associated that any one would have served to characterize the various lots for comparative purposes.

Compressibility was closely associated with these three properties, because, as measured here, it was principally a measure of stiffness of the leather fibers and fiber network. During a compressibility test, the percentage of voids in the leather was reduced on the average only from 72 to 49 per cent, so that hardness of the leather substance was a minor factor.

Set and apparent density were highly correlated; leathers of low density under the test conditions were permanently deformed more than those of higher density.

The coefficient of kinetic friction was determined to learn if it would be a measure of surface smoothness determined by hand, but the correlation coefficient was only -0.04. The friction measurement was probably influenced most by apparent density or compressibility, but it seems uncertain just what property was being measured.

Tensile strength had little relation to any of the other properties.

TABLE XV

Relation between Tanners' Grades and Physical Properties

Tanner and Grade	Thickness	Apparent Density	Stretch at Load of 10.6 kg/cm²	Stiffness by Fold	Stiffness in Flexure	Coefficient of Friction
	microns	gm/cm³	Per cent	mm	kg/cm²	
Tanner A						
Grade 5	750	0.419	4.94	64.8	180	32.6
Grade 4	700	.424	4.08	66.1	195	31.8
Grade 3	700	.435	3.16	67.9	260	31.9
Grade 2	671	.435	3.76	65.0	234	32.4
Grade 1	652	.431	2.39	70.6	352	31.8
Tanner B						
Grade 5	771	.422	4.96	65.5	175	32.2
Grade 4	713	.428	3.98	66.9	208	31.6
Grade 3	738	.420	4.59	65.6	199	32.6
Grade 2	672	.428	3.66	65.6	233	32.4
Grade 1	664	.434	3.07	67.3	279	32.0

Correlations Between Physical Properties and Feel

For a study of the relation between feel and physical properties, data on the individual skiver basis were available from 6 tests. Average values for each property and each tanner are shown in Table XV, and Table XVI gives an analysis of variance of this data.

TABLE XVI

Analysis of Variance of Grade Data of Table XV

Tanner and Source of Variation	Degrees of Freedom	Mean Squares[1] for Thickness	Apparent Density	Stretch	Stiffness by Fold	Stiffness in Flexure	Coefficient of Friction
Tanner A							
Between grades							
Regression	1	1722**	600**	87.6**	239	2785[2]	4.0
Deviation from regression	3	56	80	8.2	117*	283*	4.2
Within grades	160	69	65	3.6	40	73	6.2
Tanner B							
Between grades							
Regression	1	2310**	294*	66.4**	34	1773**	0.4
Deviation from regression	3	143	76	5.1	24	73	5.3
Within grades	160	64	67	3.8	42	83	6.2

[1] Mean squares for thickness are in hundreds; for apparent density in hundred thousandths; for stiffness in flexure in thousands; * significant beyond 5 per cent point, ** significant beyond 1 per cent point.

[2] Significant at approximately the 6 per cent point.

Highly significant differences between grades were found for thickness, stretch and stiffness in flexure. Also, for tanner A there was a significant difference in apparent density. The tanners preferred a thick, stretchy, flexible leather.

Correlation coefficients for feel and the various physical properties, based on lot averages, are shown in Table XVII. These coefficients also show that the important properties were thickness, stretch, and stiffness in flexure or bending modulus. Bending length, which involves drape, was not closely related to feel, nor was flexural rigidity, which is a measure of stiffness disregarding thickness and density of the leather.

Species Comparisons

The first step in comparing the physical properties of leathers made with different species of sumac was to note which properties showed differences related to species. The mean squares given in Table XI show there were no significant differences ascribable to species in weight per unit area, acid deterioration, heat deterioration, compressibility or real density. For the

TABLE XVII

Correlations between Feel and Chemical or Physical Properties

Property	Grade of Tanner A	Grade of Tanner B
	r	r
Grade of Tanner A	1.00	0.83**
Combined tannin	.60	.70*
Degree of tannage	.56	.71*
Surface smoothness	.57	.80**
Thickness	.76**	.81**
Apparent density	-.81**	-.65*
Stretch	.81**	.63*
Stiffness by fold	-.83**	-.71*
Stiffness in flexure	-.76**	-.58
Bending modulus	-.64*	-.50
Bending length	-.52	-.46
Flexural rigidity	-.45	-.38
Set	.50	.24
Coefficient of friction	.70*	.34
Compressibility	.52	.37
Shrinkage temperature	.76**	.53

*Significant beyond 5 per cent point.
**Significant beyond 1 per cent.

last three properties, however, there were significant differences between lots, so species differences may have been obscured. Although loss in tensile strength by acid deterioration was not significant, *Rhus coriaria* leather lost least, and *R. copallina* leather was next in order. This fact, combined with the other information given in Table XII, in an indication (but requiring confirmation) that *R. coriaria* was somewhat more resistant to acid deterioration than the other three leathers and that *R. copallina* leather was slightly better than the remaining two kinds.

For those qualities found to be important for feel, namely, thickness, stretchiness, flexibility and low apparent density, the order of decreasing value for species was *Rhus copallina*, *R. coriaria*, *R. glabra* and *R. typhina*. Shrinkage temperature averages and also degree of tannage followed this same order, except for reversal of the last two, *R. glabra* leather having a lower shrinkage temperature and degree of tannage than *R. typhina* leather.

Set was least for *Rhus coriaria* and greatest for *R. copallina* leather. Low set, or good recovery after deformation, might be important for some types of leather.

For leathers tanned with domestic sumacs, the order of decreasing tensile strength was *Rhus glabra*, *R. typhina*, *R. copallina* leather. As. low tensile strength would never be desirable, *R. copallina* was undesirable for this reason, but this may be a necessary consequence of the softness and more open leather produced by this species of sumac. The position of *R. coriaria* leather as regards tensile strength cannot be determined from the data at hand. The data in Table X show it to be lowest in strength. However, the untreated control strips used for the gas chamber deterioration study (specimens from 6 skivers per lot) had the following average tensile strengths: *R. copallina* leather, 27.9 kilograms per square centimeter; *R. typhina leather*, 36.2; *R. coriaria* leather, 37.3; and *R. glabra* leather, 40.4. In this test and also in that reported in Table IV, the *R. coriaria* tanned leather had comparatively high strength

In lightness (color) *Rhus coriaria* leather had the highest average value (Table IX), but neither the differences between lots nor between species were statistically significant. However, there were only 2 skivers per lot. The color values given in the previous publication[4] show that *R. coriaria* leather had the highest average reflectance for green light, and although the species mean square was not significant at the 5 per cent point, it was at about the 8 per cent point. This lack of higher significance probably is caused partly by the contribution of the skin itself to the over-all color.

The data in Table X were also examined for differences due to materials by the method described earlier. There were differences between leaves and leaflets for stretch, apparent density and compressibility of the leathers; leaflets produced leather with more stretch and compressibility but lower apparent density than leaves. These results are based of course only on one sample with *R. glabra* leaflets and two with *R. typhina* leaflets and so are by no means conclusive.

Although it has not been possible to show significant differences between species at definite levels in all cases, because of the incomplete data, the following tentative conclusions seem justified.

Rhus copallina produced leather with the best feel, greatest thickness and stretch, the highest degree of tannage and the lowest apparent density and stiffness. *Rhus glabra* produced leather with the greatest tensile strength. *Rhus coriaria* leather had the best recovery after bending, and there is good evidence that it was lightest in color and had the best resistance to acid deterioration.

Summary

Eleven lots of sumac-tanned sheepskin leather from a commercial test were graded by two tanners for tannage or "feel", then subjected to numerous physical tests in the laboratory. The leathers were tanned with Sicilian sumac (*Rhus coriaria*) and leaves of three domestic species, *R. copallina*, *R. glabra* and *R. typhina*.

The order of decreasing value of the species, based on tanning quality, was *Rhus copallina*, *R. coriaria*, *R. glabra* and *R. typhina.*

The tanners' evaluations were associated with thickness, stretch, stiffness, and apparent density. They favored a relatively thick, stretchy, flexible leather. The following tests did not prove to be important: real density, bending length, flexural rigidity, compressibility and set.

Correlations between tests are discussed.

Differences in thickness, apparent density, tensile strength, stretch, stiffness in flexure, set, and shrinkage temperature were associated with species characteristics, the order of decreasing value of the species being in most cases the same as that given above for tanning quality. Tensile strength was not correlated with any other test; *Rhus glabra* leather was strongest *and R. copallina* leather was weakest.

Color measurements in the I.C.I. system and in Munsell notation are reported. *Rhus coriaria* leather was a little whiter than the others, the differences being significant at about 8 per cent point.

In general, with respect to thoroughness of tannage and leather quality, these tests indicate that *Rhus copallina* produced the best leather and *R. coriaria* the next best.

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